

FIELD OF THE INVENTION

BACKGROUND OF THE INVENTION

In figure 19, the prior art waveform equalization controller comprises a waveform equalizer 101 for receiving

Figure 20 is a diagram illustrating a structure of a signal format according to the DTV system. As shown in figure 20, the signal format according to the DTV system is composed of areas including a data signal 3101 such as video and audio, areas including a field synchronous signal 3102, and an area including a segment synchronous signal 3103.

Figure 21 is a diagram illustrating a structure of the field synchronous signal. As shown in figure 21, the field synchronous signal 3102 includes a PN511 signal 3201, three PN63 signals 3202, and a control signal 3203. The difference between the field synchronous signal #2 and the

field synchronous signal #1 is only that the second value in the PN63 signal 3202 is reversed. In figure 21, values on the left side (+7, +5, +3, +1, -4, -3, -5, -7) show 8 kinds of values which are taken on in the 8-value VSB modulation technique. One field of this DTV signal is composed of 832 symbols and 313 segments. The PN511 signal 3201 is obtained by a generating polynomial:

PN511= $X^9+X^7+X^6+X^4+X^3+X+1$ (in this polynomial, " $^$ " shows the power) and represented by Pre-load 010000000 (binary representation of the initial value). The PN63 signal 3202 is obtained by $PN63=X^6+X+1$ and represented by Pre-load 100111. The PN511 signal 3201 is composed of 511 symbols. The PN63 signals 3202 are composed of 63 symbols, respectively. The control signal 3203 is composed of 128 symbols. The whole of the field synchronous signal 3102 is composed of 828 symbols.

Next, the operation of the prior art waveform equalization controller is described with reference to the figures. In the waveform equalization controller according to the DTV system, as shown in figure 19, the waveform equalizer 101 performs the waveform equalization to the DTV signal which has been subjected to the 8-value modulation to reduce the distortion, and generates the output signal 101S. Then, the output error estimation unit 1502 generates the error between the output signal 101S and

The LMS algorithm is the algorithm of performing the n-th update of tap coefficient C_i of tap i in a transversal filter in the waveform equalizer 101 on the basis of the following Expression 1.

Here, α denotes the step size 104S, $e(n)$ denotes the error signal 1901S, $di(n)$ denotes the coefficient updating data 105S, and $-\alpha \times e(n) \times di(n)$ denotes the tap coefficient updating amount 106S. Here, the coefficient updating data

105S is a data in tap i at the n-th updating.

There are two methods for generating the output error signal 1501S in the output error estimation unit 1502. One of the methods is capturing the PN511 signal 3201 and the PN63 signal 3203 included in the field synchronous signal 3102 in the DTV signal, comparing the signals with ideal values of the PN511 signal 3201 and the PN63 signal 3202, and outputting the error thereof as the output error signal 1501S.

The other method is comparing a data signal 3101 which is inserted in the data period of the DTV signal with the nearest fixed value of the 8-value VSB modulation, and outputting the error thereof as the output error signal 1501S.

Since the 8-value VSB modulation technique is used, the DTV signal has 8 kinds of values (+7, +5, +3, +1, -1, -3, -5, -7) as shown in figure 21. However, when the DTV signal which has been subjected to the 8-value VSB modulation is received, the signal is generally quantized in about 10 bits. For example in the case where the DTV signal which has been quantized in 10 bits does not have any distortion, only 8 kinds of fixed values can be taken on for the values represented by 10 bits (0 to 1023). The output error estimation unit 1502 calculates the error for the field synchronous signal 3102 of the input DTV signal

The prior art waveform equalization controller is constructed as described above and when this waveform equalization controller is used, it is possible that the waveform equalizer can be controlled and the DTV signal whose distortion is reduced can be obtained.

However, the prior art waveform equalization controller has following problems.

The first problem is that the step size as the update step of the tap coefficient is fixed. Generally, when the step size is increased, the follow-up property in the case where the distortion is varied or the convergence speed at the initial operation is increased. On the other hand, the waveform equalization controller is easily affected by

The second problem is that two multipliers are required in the coefficient updating amount calculation unit to calculate the coefficient updating amount of one tap, whereby the circuit scale becomes larger.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a waveform equalization controller which has both of the good follow-up property in the case where the distortion of the signal is varied or the higher convergence speed at the initial operation and the good stability at the low C/N time,

Other objects and advantages of the present invention will become apparent from the detailed description and specific embodiments described are provided only for illustration since various additions and modifications within the spirit and scope of the invention will be apparent to those of skill in the art from the detailed description.

A waveform equalization controller according to a 1st aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; a step size decision unit for receiving the error signal and a step size upper limit value and a step size lower limit value being an upper limit value and a lower limit value of a step size as a step for the update of the tap coefficient, adaptively generating a step size which corresponds to the error signal in a range of the step size upper limit value or smaller and the step size lower limit value or larger, and outputting the generated step size; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis

According to a 2nd aspect of the present invention, in the waveform equalization controller of the 1st aspect, the step size decision unit comprises: a multiplier for squaring the error signal to generate a square error; a square error storage unit for containing the square error which has been generated at a previous tap coefficient update; a subtracter for generating a difference between square errors, which is a difference between the square error output by the multiplier and the square error stored in the square error storage unit generated at the previous tap coefficient update; a first comparator for comparing the square error with a first threshold; a second comparator for comparing the square error with a second threshold; a third comparator for comparing an absolute value of the difference between square errors with a third threshold; a step size storage unit for containing a step size which has been used at the previous tap coefficient update; and a step size increasing/decreasing unit for receiving the step size

According to a 3rd aspect of the present invention, in the waveform equalization controller of the 2nd aspect, the second threshold is such a value that when the square error is larger than the value the waveform equalizer is trending toward divergence; the first threshold is such a value that when the square error is smaller than the value the waveform equalizer is either converging or has converged; the third threshold is such a value that in the case where the square error is smaller than the first threshold, when an absolute value of the difference between square errors is larger than the third threshold the waveform equalizer is converging and when the absolute value is equal to or smaller than the third threshold the waveform equalizer has converged; and the step size increasing/decreasing unit decreases the step

According to a 4th aspect of the present invention, in the waveform equalization controller of the 2nd aspect, the second threshold is such a value that when the square error is larger than the value the waveform equalizer is trending toward divergence; the first threshold is such a value that when the square error is smaller than the value the waveform equalizer is either converging or has converged; the third

A waveform equalization controller according to a 5th

According to a 6th aspect of the present invention, in the waveform equalization controller of the 5th aspect, the

According to a 7th aspect of the present invention, in the waveform equalization controller of the 6th aspect, the step size decision unit outputs a first step size set value as the step size when the judgement signal indicates that the output signal is known, outputs a second step size set value which is smaller than the first step size set value when the judgement signal indicates that the probability of the judgement error for the output signal is smaller, and outputs a third step size set value which is smaller than the second step size set value when the judgement signal indicates that the probability of the judgement error for the output signal is larger. Therefore, the step size can

A waveform equalization controller according to an 8th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of the output signal of the waveform equalizer from the output signal, and outputting an error signal; a step size decision unit for receiving the error signal, a threshold and plural step size set values, and deciding a step size as a step for the update of the tap coefficient; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update. Therefore, one of the step sizes can be selected according to the relationship between the error signal and the threshold, whereby the waveform equalization controller which has a follow-up property in the case where the transmission line distortion

According to a 9th aspect of the present invention, in the waveform equalization controller of the 8th aspect, the plural step size set values are a first step size set value and a second step size set value which is larger than the first step size set value, and the step size decision unit comprises: a comparator for comparing an absolute value of the error signal with the threshold; and a selector for selecting one of the first step size set value and the second step size set value on the basis of a comparison result output by the comparator, and outputting the selected step size as the step size. Therefore, one of the step sizes can be selected on the basis of the result of the comparison between the error signal and the threshold, whereby the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 10th aspect of the present invention, in the waveform equalization controller of the 9th aspect, the threshold value is such a value that when the absolute value of the error signal is equal to or smaller than the threshold the waveform equalizer has nearly converged; and the step size decision unit outputs the first step size set

A waveform equalization controller according to a 11th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; an error quantization unit for converting the error signal into a quantized error signal having a value of powers of 2, and outputting the quantized error signal; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis

According to a 12th aspect of the present invention, in the waveform equalization controller of the 11th aspect, the error quantization unit converts the error signal into the quantized error signal having the same sign as the error signal and a maximum absolute value which is equal to or smaller than an absolute value of the error signal among the powers of 2, and outputting the quantized error signal. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art as well as has a small circuit scale can be realized.

According to a 13th aspect of the present invention, in the waveform equalization controller of the 11th aspect, the error quantization unit converts the error signal into the quantized error signal having the same sign as the error

A waveform equalization controller according to a 14th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; a data quantization unit for converting a data to be used for the tap coefficient update into a quantized data having a value of powers of 2, and outputting the quantized data; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and the quantized data. Therefore, the two-time multiplication which is required

in the prior art can be replaced with one multiplication and one shift operation, whereby the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

According to a 15th aspect of the present invention, in the waveform equalization controller of the 14th aspect, the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having the same sign as the data to be used for the tap coefficient update and a maximum absolute value which is equal to or smaller than an absolute value of the data to be used for the tap coefficient update among the powers of 2, and outputting the quantized date. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

According to a 16th aspect of the present invention, in the waveform equalization controller of the 14th aspect, the data quantization unit converts the data to be used for the tap coefficient update into a quantized data having the same sign as the data to be used for the tap coefficient update and a minimum absolute value which is equal to or

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A waveform equalization controller according to a 17th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal; a step size quantization unit for converting a step size as a step for the update of the tap coefficient into a quantized step size having a value of powers of 2, and outputting the quantized step size; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, the quantized step size and a data to be used for the tap coefficient update. Therefore, the two-time

According to an 18th aspect of the present invention, in the waveform equalization controller of the 17th aspect, the step size quantization unit converts the step size into the quantized step size having a maximum value which is equal to or smaller than the step size among the powers of 2, and outputs the quantized step size. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can be replaced with one multiplication and one shift operation. Thus, the waveform equalization controller which attains the same performance as the prior art and has a small circuit scale can be realized.

According to a 19th aspect of the present invention, in the waveform equalization controller of the 17th aspect, the step size quantization unit converts the step size into the quantized step size having a minimum value which is equal to or larger than the step size among the powers of 2, and outputting the quantized step size. Therefore, the two-time multiplication is required to obtain the tap coefficient updating amount in the prior art while it can

A waveform equalization controller according to a 20th aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit for estimating an error of an output signal of the waveform equalizer from the output signal, and outputting an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the output signal; a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update; and a coefficient update timing control unit for receiving the error signal and outputting a update timing signal which controls a timing when the coefficient updating amount calculation unit calculates the tap coefficient updating amount at intervals of plural symbols. Therefore, the tap coefficient updating amount is calculated by the

aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm, and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error estimation unit comprising an output error estimation unit for receiving an output signal of the waveform equalizer and outputting an output error signal, and a coefficient updating error generation unit for receiving the output error signal and the output signal and outputting an error signal which is obtained by reducing a partial section of the output error signal at a predetermined rate; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a date to be used for the tap coefficient update. Therefore, the output error signal which has been converted into "0" by the coefficient updating error generation unit is converted into an error signal which is obtained by multiplying the output error signal by a predetermined rate to decrease the value. Thus, the error signal which can be used for the tap coefficient update is increased in number as compared to Stop&Go algorithm. Therefore, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input

A waveform equalization controller according to a 23rd aspect of the present invention which comprises a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm and controls update of a tap coefficient of a filter included in the waveform equalizer comprises: an error rate measuring circuit for receiving an output signal of the waveform equalizer and generating an error rate signal which indicates a rate of an error included in the output signal; an error estimation unit comprising an output error estimation unit for receiving the output signal of the waveform equalizer and outputting an output error signal, and a coefficient updating error generation unit for receiving the output error signal, the output signal and the error rate signal and outputting an error signal; and a coefficient updating amount calculation unit for calculating a tap coefficient updating amount on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update. Therefore, the update interval of the tap coefficient is reduced and further the error signal which can be used for the tap coefficient update is increased in number. Thus, the waveform equalization controller

which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

According to a 24th aspect of the present invention, in the waveform equalization controller of the 23rd aspect, the coefficient updating error generation unit outputs the same value as the output error signal, as the error signal, when it is detected from the error rate signal that the rate of the error included in the output signal is smaller than a predetermined rate. Therefore, the update interval of the tap coefficient is reduced and further the error signal which can be used for the tap coefficient update is increased in number. Thus, the waveform equalization controller which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 25th aspect of the present invention for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal,

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and generating an error signal; a step size decision step of adaptively deciding a step size in a range of a step size upper limit value as an upper limit value of a step size which is a step for the update of the tap coefficient or smaller, and a step size lower limit value as a lower limit value of the step size or larger, on the basis of the error signal; and a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, the step size and a data to be used for the tap coefficient update. Therefore, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

According to a 26th aspect of the present invention, in the waveform equalization control method of the 25th aspect, the step size decision step comprises: a multiplication step of squaring the error signal to generate a square error; a subtraction step of generating a difference between square errors, which is a difference between the square error generated at a previous tap coefficient update and the square error generated in the multiplication step; a first comparison step of comparing the square error with a first threshold; a second comparison

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step of comparing the square error with a second threshold; a third comparison step of comparing an absolute value of the difference between square errors with a third threshold; and a step size generation step of generating a step size which is to be used for this tap coefficient update on the basis of the step size which has been used at the previous tap coefficient update, a comparison result in the first comparison step, a comparison result in the second comparison step, a comparison result in the third comparison step, the step size upper limit value and the step size lower limit value. Therefore, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation, is hardly affected by noises, and has a higher stability at a low C/N time can be realized.

A waveform equalization control method according to a 27th aspect for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: a step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal; a step of judging whether a probability of a judgement error in the error estimation for the output signal is larger or smaller, and

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A waveform equalization control method according to a 28th aspect of the present invention for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an error estimation step of estimating an error of the output signal of the waveform equalizer from the output signal, and generating an error signal; a step size decision step of deciding a step size as a step for the update of the tap coefficient on the basis of the error signal, a threshold and plural step size set values; and a coefficient updating amount calculation step of calculating a tap coefficient updating amount on the basis of the error signal, the step

According to a 29th aspect of the present invention, in the waveform equalization control method according to the 28th aspect, the plural step size set values are a first step size set value and a second step size set value which is larger than the first step size set value, and the step size decision step comprises: a comparison step of comparing an absolute value of the error signal with the threshold; and a selection step of selecting one of the first step size set value and the second step size set value as the step size on the basis of a comparison result in the comparison step. Therefore, one of the step sizes can be selected on the basis of the result of the comparison between the error signal and the threshold, whereby the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 30th aspect of the present invention for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an error estimation step of estimating an error of an output signal of the waveform equalizer from the output signal, and generating an error signal which is obtained by making the estimated error 0 when the estimated error is an error corresponding to a predetermined range of the output signal; a coefficient update timing control step of generating an update timing signal which controls a timing of calculating the tap coefficient updating amount at intervals of plural symbols on the basis of the error signal; and a coefficient updating amount calculation step of calculating a tap coefficient updating amount at the timing controlled by the update timing signal on the basis of the error signal, a step size as a step for the update of the tap coefficient and a data to be used for the tap coefficient update. Therefore, the tap coefficient updating amount is calculated in the coefficient updating amount calculation step when the error signal is not "0", whereby the coefficient updating interval can be reduced with relative to the waveform equalization control method for performing the coefficient update at a predetermined symbol intervals.

According to a 31st aspect of the present invention, in the waveform equalization control method of the 30th aspect, the update timing signal is generated for controlling the timing of calculating the tap coefficient updating amount in the coefficient update timing control step to be at a first symbol after an interval of predetermined symbols or more from a previous timing and when the error signal is not 0. Therefore, the coefficient updating interval can be reduced with relative to the waveform equalization control method for performing the coefficient update at previously determined symbol intervals. Thus, the waveform equalization control method which has a follow-up property in the case where the transmission line distortion of the input signal is varied and a higher convergence speed at the initial operation can be realized.

A waveform equalization control method according to a 32nd aspect for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: a step of estimating an output

A waveform equalization control method according to a 33rd aspect for controlling update of a tap coefficient of a filter included in a waveform equalizer for reducing a transmission line distortion of an input signal on the basis of LMS algorithm comprises: an output error estimation step

According to a 34th aspect of the present invention, in the waveform equalization control method according to the 33rd aspect, when it is detected from the error rate signal in the coefficient updating error generation step that the rate of the error included in the output signal

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 2 is a block diagram illustrating a structure of a step size decision unit according to the first embodiment.

Figure 4 is a block diagram illustrating a waveform equalization controller according to a second embodiment of the present invention.

Figure 5 is a diagram showing the relationship between a judgement signal and an output signal of the waveform equalization controller according to the second embodiment.

Figure 6 is a block diagram illustrating a structure of a waveform equalization controller according to a third embodiment of the present invention.

Figure 7 is a block diagram illustrating a structure of a waveform equalization controller according to a fourth embodiment of the present invention.

Figure 8 is a diagram showing the relationship between an error signal and a quantized error signal of the waveform equalization controller according to the fourth embodiment.

Figure 9 is a block diagram illustrating a structure of a waveform equalization controller according to a fifth embodiment of the present invention.

Figure 10 is a diagram showing the relationship between a data and a quantized data of the waveform equalization controller according to the fifth embodiment.

Figure 11 is a block diagram illustrating a structure of a waveform equalization controller according to a sixth embodiment of the present invention.

Figure 12 is a diagram showing the relationship between a step size and a quantized step size of the waveform equalization controller according to the sixth embodiment.

Figure 13 is a block diagram illustrating a structure of a waveform equalization controller according to a seventh embodiment of the present invention.

Figures 14(a)-14(d) are diagrams for explaining the

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timing of tap coefficient update in the waveform equalization controller according to the seventh embodiment.

Figure 15 is a block diagram illustrating a structure of a waveform equalization controller according to an eighth embodiment of the present invention.

Figures 16(a)-16(b) are diagrams for explaining the operation of the waveform equalization controller according to the eighth embodiment of the present invention.

Figure 17 is a block diagram illustrating a structure of a waveform equalization controller according to a ninth embodiment of the present invention.

Figures 18(a)-18(d) are diagrams for explaining the operation of the waveform equalization controller according to the ninth embodiment of the present invention.

Figure 19 is a block diagram illustrating a structure of a prior art waveform equalization controller.

Figure 20 is a diagram illustrating a structure of a DTV signal format.

Figure 21 is a diagram illustrating a structure of a field synchronous signal format in the DTV signal.

Figures 22(a)-22(b) are diagrams for explaining the operation of the prior art waveform equalization controller.

Figure 23 is a flowchart showing the operation of the

Figure 24 is a flowchart showing the operation of the waveform equalization controller according to the first embodiment.

Figure 25 is a flowchart showing the operation of the waveform equalization controller according to the second embodiment.

Figure 26 is a flowchart showing the operation of the waveform equalization controller according to the third embodiment.

Figure 27 is a flowchart showing the operation of the waveform equalization controller according to the seventh embodiment.

Figure 28 is a flowchart showing the operation of the waveform equalization controller according to the eighth embodiment.

Figure 29 is a flowchart showing the operation of the waveform equalization controller according to the ninth embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, a waveform equalization controller and a waveform equalization control method according to embodiments of the present invention will be described with reference to the drawings.

A waveform equalization controller and a waveform equalization control method according to the first embodiment of the present invention will be described with reference to the figures.

Figure 1 is a block diagram illustrating a structure of the waveform equalization controller according to the first embodiment. In figure 1, the waveform equalization controller of the first embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and a data 105S to be used for coefficient update, and a step size decision unit 104 for receiving the error signal 102S, a step size upper limit value 107S and a step size lower limit value 108S, and generating and outputting the step size 104S.

Figure 2 is a block diagram illustrating a structure of the step size decision unit 104 included in the waveform equalization controller of the first embodiment. In figure

2, the step size decision unit 104 comprises a multiplier 201 for squaring the error signal 102S and generating a square error 201S, a square error storage unit 202 for containing the square error 201S, a subtracter 203 for calculating the difference between the square error 201S output by the multiplier 201 and the square error stored in the square error storage unit 202 and outputting the difference 202S between the square errors, a first comparator 204 for comparing the square error 201S with a first threshold, a second comparator 205 for comparing the square error 201S with a second threshold, a third comparator 206 for comparing the absolute value of the difference 202S between the square errors with a third threshold, a step size storage unit 207 for containing the step size, and a step size increasing/decreasing unit 208.

Next, the operation of the waveform equalization controller according to the first embodiment is described with reference to the figures.

Figure 23 is a flowchart showing the operation of the waveform equalization controller according to the first embodiment.

Initially, a signal from the transmission line is input to the waveform equalizer 101 as the input signal 100S via a tuner and a wave detector (not shown). The error estimation unit 102 estimates an error to be used for the

The step size decision unit 104 receives the error signal 102S, the step size upper limit value 107S as a value for deciding the upper limit of the step size and the step size lower limit value 108S as a value for deciding the lower limit of the step size, decides the step size 104S, the value of which is varied according to the error signal 102S within a range of the step size lower limit value 108S or larger

and the step size upper limit value 107S or smaller, and outputs the step size 104S (step S102). The coefficient updating amount calculation unit 103 receives the error signal 102S, the step size 104S and the data 105S, performs the multiplication of these as shown in the second term on the right side in the above-mentioned (Expression 1), and outputs the tap coefficient updating amount 106S (step S103). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S101 to S103 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

As the data 105S used for the coefficient update, data which are stored in a data FIFO (not shown) included in the waveform equalizer 101 are employed. The waveform equalization controller can separately comprise a FIFO for containing the coefficient updating data 105S. Further, as the upper limit value 107S of the step size and the lower limit value 108S of the step size, values which have previously been stored in a register (not shown) included in the waveform equalization controller are employed.

Next, the operation of the step size decision unit 104 is described.

Figure 24 is a flowchart showing the operation of the

The multiplier 201 squares the error signal 102S to generate the square error 201S (step S201). The square error storage unit 202 contains the square error at the previous coefficient updating. The subtracter 203 calculates the difference between the square error 201S and the square error at the previous coefficient updating, and outputs the difference 202S of the square errors (step S202). Then, the square error storage unit 202 contains the present square error 201S. The first comparator 204 compares the square error 201S with the first threshold (step S203). The second comparator 205 compares the square error 201S with the second threshold (step S204). The third comparator 206 compares the absolute value of the difference 202S of the square errors with the third threshold (step S205). The comparison result of the first comparator 204, the comparison result of the second comparator 205, the comparison result of the third comparator 206, the step size at the previous coefficient updating stored in the step size storage unit 207, the step size upper limit value 107S and the step size lower limit value 108S are input to the step size increasing/decreasing unit 208.

When the square error 201S is larger than the second threshold, the waveform equalization operation for reducing the transmission line distortion in the waveform equalizer

101 is in an uncontrollable state, i.e., trending toward divergence. On the other hand, when the square error 201S is smaller than the first threshold, the waveform equalization operation in the waveform equalizer 101 is either converging or has converged. When the square error 201S is smaller than the first threshold, and when the absolute value of the difference 202S between the square errors is larger than the third threshold, the waveform equalization operation in the waveform equalizer 101 is converging, and when the absolute value is equal to or smaller than the third threshold, the waveform equalization operation in the waveform equalizer 101 has converged.

Practically, rough values of the first to third thresholds are set by simulation, and then the first to third thresholds are finally set on the judgement of the designer made by considering the result of the actual operation, respectively.

To be specific, the second threshold is set to such a value that the designer judges when the square error 201S is larger than that value, the waveform equalization operation in the waveform equalizer 101 is trending toward divergence. The first threshold is set to such a value that the designer judges when the square error 201S is smaller than that value, the waveform equalization operation in the waveform equalizer 101 is either converging or has converged.

Then, the operation of the step size increasing/decreasing unit 208 is described with reference to the figures.

In figure 3, when the square error 201S is within an area 1, i.e., when it is judged by the second comparator 205 that the square error 201S is larger than the second threshold, it is judged that the waveform equalizer 101 is trending to divergence. Therefore, the step size increasing/decreasing unit 208 obtains a new step size which is obtained by decreasing the previous step size stored in the step size storage unit 207 by a prescribed amount.

When the square error 201S is within an area 2, i.e., it is judged by the first comparator 204 and the second

When the square error 201S and the difference 202S between the square errors are within an area 3 or area 5, i.e., it is judged by the first comparator 204 that the square error 201S is smaller than the first threshold and it is judged by the third comparator 206 that the absolute value of the difference 202S between the square errors is larger than the third threshold value, the waveform equalizer 101 is judged to be converging. Therefore, the step size increasing/decreasing unit 208 obtains a new step size which is obtained by increasing the previous step size stored in the step size storage unit 207 by a prescribed amount to increase the convergence speed more. Here, the step size is increased in the area 5 to also suitably cope with dynamic ghost, i.e., ghost varying with time.

When the square error 201S and the difference 202S between the square errors are within an area 4, i.e., it is judged by the first comparator 204 and the third comparator 206 that the square error 201S is smaller than the first threshold and the absolute value of the difference

202S between the square errors is equal to or smaller than the third threshold, the waveform equalizer 101 is judged to have almost converged. Therefore, the step size increasing/decreasing unit 208 obtains a new step size which is obtained by decreasing the previous step size stored in the step size storage unit 207 by a prescribed amount to ensure the stability at the low C/N time.

Further, when the new step size is larger than the step size upper limit value 107S, the step size increasing/decreasing unit 208 outputs the step size upper limit value 107S as the step size 104S. When the new step size is smaller than the step size lower limit value 108S, the step size increasing/decreasing unit 208 outputs the step size lower limit value 108S as the step size 104S. In other cases, the new step size is output as the step size 104S (step S206).

As described above, according to the waveform equalization controller of the first embodiment, the step size decision unit 104 is provided which judges the status of the waveform equalizer 101 from the square error 201S and the difference 202S between the square errors, and obtains the suitable step size 104S by correspondingly increasing or decreasing the previous step size. Thus, the waveform equalization controller having a higher convergence speed and a higher stability at the low C/N time

can be realized.

In this first embodiment, the square error is used as the index for increasing or decreasing the step size. However, the index for increasing or decreasing the step size is not limited to the square error. The same function can be attained also with the n -th power of the error (" n " is 1 or an integer of 3 or more). In this case, when " n " is an odd number, the absolute value of the n -th power of the error is used for example in the first comparator 204 or second comparator 205 as the n -th power error.

Further, in this first embodiment, when the step size increasing/decreasing unit 208 increases/decreases the step size, a prescribed amount is added/subtracted to/from the previous step size. However, the way of increasing/decreasing the step size is not limited to this. The step size can be increased/decreased by increasing/decreasing the previous step size by a prescribed ratio. To be specific, when the step size is to be increased, the previous step size is multiplied by a prescribed value which is larger than 1, for example 1.1. When the step size is to be decreased, the previous step size is multiplied by a prescribed value which is smaller than 1, for example 0.9.

[Embodiment 2]

A waveform equalization controller according to the

Figure 4 is a block diagram illustrating a structure of the waveform equalization controller according to the second embodiment. In figure 4, the waveform equalization controller of the second embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and a data 105S to be used for the coefficient update, a signal judgement unit 401 for outputting a judgement signal 401S, and a step size decision unit 402 for outputting the step size 104S in accordance with the judgement signal 401S.

Figure 25 is a flowchart showing the operation of the waveform equalization controller according to the second embodiment.

The error estimation unit 102 estimates the error to

Hereinafter, the description is given taking a case where the input to the waveform equalizer 101 is a DTV signal as an example. Figure 5 shows the relationship between the judgement signal 401S and the output signal 101S. In figures 20 and 21, the symbol values of the segment synchronous signal 3103, and the PN511 signal 3201 and the PN63 signal 3202 in the field synchronous signal are previously known. Therefore, no judgement error occurs in the error estimated by the error estimation unit 102 for the output signal 101S. In this case, the error signal 102S always shows a correct value. Therefore, the signal judgement unit 401 outputs "0" as the judgement signal 401S. The control signal 3203 can take on only two values among eight values of the DTV signal. Therefore, the probability of the judgement error in the error estimated by the error

estimation unit 102 for the output signal 101S is low. In this case, the error signal 102S shows a nearly correct value. Therefore, the signal judgement unit 401 outputs "1" as the judgement signal 401S. Other signals can take on all of the eight values among eight values of the DTV signal. Thus, the probability of the judgement error in the error estimated by the error estimation unit 102 for the output signal 101S is high. Since the probability of the error signal 102S showing a correct value is low in this case, the signal judgement unit 401 outputs "2" as the judgement signal 401S.

The step size decision unit 402 selects one of three kinds of step sizes which have previously been set according to the values of the judgement signal 401S, and outputs the selected step size 104S. When the judgement signal 401S is "0", the largest step size is output as the step size 104S. When the judgement signal 401S is "1", the second largest step size is output as the step size 104S. When the judgement signal 401S is "2", the smallest step size is output as the step size 104S (step S303). The coefficient updating amount calculation unit 103 receives the error signal 102S, the step size 104S and the data 105S, performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S304). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101

to update the tap coefficient shown by (Expression 1). Here, the processes of steps S301 to S304 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

As described above, according to the waveform equalization controller of the second embodiment, the signal judgement unit 401 for outputting the judgement signal 401S according to the probability of the judgement error in the error by the error estimation unit 102 in regard to the output signal 101S, and the step size decision unit 402 for outputting one of the step sizes which have previously been set according to the judgement signal 401S are provided. Therefore, the value of the step size 104S can be changed according to the probability of the judgement error in the error estimation for the output signal 101S. When the error signal 102S is correct, the tap coefficient updating amount 106S is increased. Therefore, the convergence speed can be increased, whereby the waveform equalization controller having a higher convergence speed and a higher stability at the low C/N time can be realized.

In this second embodiment, the description is given of a case where the input signal 100S is the DTV signal. However, the input is not limited to the DTV signal. In addition, while the judgement signal 401S is set to have

Further, in this second embodiment, the description is given of a case where the signal judgement unit 401 generates the judgement signal 401S using the synchronous signal included in the input signal 100S. However, the signal judgement unit 401 can generate the judgement signal 401S using the synchronous signal included in the output signal 101S.

A waveform equalization controller according to the third embodiment of the present invention will be described with reference to the figures.

Figure 6 is a block diagram illustrating a structure of the waveform equalization controller according to the third embodiment. In figure 6, the waveform equalization controller of the third embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of

the output signal 101S and outputting an error signal 102S, a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and a data 105S to be used for the coefficient update, and a step size decision unit 601 for receiving the error signal 102S, a threshold 601S, a first step size set value 602S and a second step size set value 603S, and generating and outputting the step size 104S. The step size decision unit 601 comprises a comparator 602 and a selector 603.

Next, the operation of the waveform equalization controller according to the third embodiment is described with reference to the figures.

Figure 26 is a flowchart showing the operation of the waveform equalization controller according to the third embodiment.

The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S (step S401). The comparator 602 compares the absolute value of the error signal 102S with the threshold 601S (step S402). From the comparison result of the comparator 602, when the absolute value of the error signal 102S is equal to or smaller than the threshold 601S, the selector 603 selects the first

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step size set value 602S and outputs the first step size set value 602S as the step size 104S. From the comparison result of the comparator 602, when the absolute value of the error signal 102S exceeds the threshold 601S, the selector 603 selects the second step size set value 603S which is a step size larger than the first step size set value 602S, and outputs the second step size set value 603S as the step size 104S (step S403). In this way, in steps S402 and S403, the step size 104S is decided on the basis of the error signal 102S, the threshold 601S, the first step size set value 602S and the second step size set value 603S. The coefficient updating amount calculation unit 103 receives the error signal 102S, the step size 104S and the data 105S, performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S404). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S401 to S404 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

The threshold 601S is set to have such a value that when the absolute value of the error signal 102S is equal to or smaller than the threshold value 601S, the waveform equalizer 101 has almost converged.

FIG. 10

As described above, according to the waveform equalization controller of the third embodiment, the step size decision unit 601 is provided which changes the magnitude of the step size 104S according to the magnitude of the error signal 102S. Therefore, in a stage where the error is large, i.e., the waveform equalizer 101 has not being converging yet, the large step size is employed to increase the convergence speed. In a stage where the error is small, i.e., the waveform equalizer 101 has almost converged, the small step size is employed to ensure the stability at the low C/N time. Accordingly, the waveform equalization controller having a higher convergence speed and a higher stability at the low C/N time can be realized.

In this third embodiment, the step size is changed at two levels. However, it is possible that plural thresholds are input to the comparator 602 and one of step sizes at three or more levels is selected by the selector 603 according to the comparison result.

[Embodiment 4]

A waveform equalization controller according to the fourth embodiment of the present invention will be described with reference to the figures.

Figure 7 is a block diagram illustrating a structure of the waveform equalization controller according to the fourth embodiment. In figure 7, the waveform equalization

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controller of the fourth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing a transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, an error quantization unit 701 for converting the error signal 102S into a quantized error signal 701S having a value of the powers of 2 and outputting the quantized error signal 701S, and a coefficient updating amount calculation unit 702 for calculating a tap coefficient updating amount 106S on the basis of the quantized error signal 701S, a step size 104S and a data 105S to be used for the coefficient update.

Next, the operation of the waveform equalization controller according to the fourth embodiment is described with reference to the figures. The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S. The error quantization unit 701 converts the error signal 102S into the quantized error signal 701S having the same sign as the signal 102S and the maximum absolute value which is equal to or smaller than the absolute value of the signal 102S among the powers of 2, and outputs the quantized error signal 701S. Figure 8

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shows the relationship between the error signal 102S and the quantized error signal 701S which is obtained by converting the error signal 102S. Here, assume that when the signal 102S is "0" the signal 701S is also "0". The coefficient updating amount calculation unit 702 receives the quantized error signal 701S, the step size 104S and the data 105S. When the quantized error signal 701S taking on only the power of 2 or "0" is used, the process of multiplying the error can be replaced with the shift operation. Thus, the coefficient updating amount calculation unit 702 substitutes one multiplication and one shift operation for the process which is performed by two-time multiplication in the prior art, and outputs the tap coefficient updating amount 106S.

As described above, according to the waveform equalization controller of the fourth embodiment, the error signal 102S is converted by the error quantization unit 701 into the quantized error signal 701S having a value of the powers of 2, and the tap coefficient updating amount 106S is obtained using the quantized error signal 701S. Therefore, the multiplication can be replaced with the shift operation in the coefficient updating amount calculation unit 702. Accordingly, only one multiplier for calculating the coefficient updating amount of one tap is required, whereby the circuit scale can be reduced.

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In this fourth embodiment, when the error signal 102S is to be converted into the quantized error signal 701S, the conversion as shown in figure 8 is performed. However, the error signal 102S can be converted into a quantized error signal 701S having the same sign as the error signal 102S and the minimum absolute value which is equal to or larger than the absolute value of the error signal 102S among the powers of 2. Or the error signal 102S can be converted into a quantized error signal 701S having the same sign as the error signal 102S and the absolute value which is the nearest to the absolute value of the error signal 102S among the powers of 2.

[Embodiment 5]

A waveform equalization controller according to the fifth embodiment of the present invention will be described with reference to the figures.

Figure 9 is a block diagram illustrating a structure of the waveform equalization controller according to the fifth embodiment. In figure 9, the waveform equalization controller of the fifth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S,

a data quantization unit 901 for converting a data 105S to be used for the coefficient update into a quantized data 901S having a value of the powers of 2 and outputting the quantized data 901S, and a coefficient updating amount calculation unit 902 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, a step size 104S and the quantized data 901S.

Next, the operation of the waveform equalization controller according to the fifth embodiment is described with reference to the figures. The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S. The data quantization unit 901 converts the data 105S into the quantized data 901S having the same sign as the data 105S and the maximum absolute value which is equal to or smaller than the data 105S among the powers of 2, and outputs the quantized data 901S. Figure 10 shows the relationship between the data 105S and the quantized data 901S which is obtained by converting the data 105S. Here, assume that when the data 105S is "0" the data 901S is also "0". The coefficient updating amount calculation unit 902 receives the error signal 102S, the step size 104S and the quantized data 901S. When the quantized data 901S taking on only the powers of 2 or "0"

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As described above, according to the waveform equalization controller of the fifth embodiment, the data 105S to be used for the coefficient update is converted by the data quantization unit 901 into the quantized data 901S having a value of the powers of 2, and the tap coefficient updating amount 106S is obtained using the quantized data 901S. Therefore, the multiplication can be replaced with the shift operation in the coefficient updating amount calculation unit 902. Accordingly, only one multiplier for calculating the coefficient updating amount of one tap is required, whereby the circuit scale can be reduced.

In this fifth embodiment, when the data 105S to be used for the coefficient update is to be converted into the quantized data 901S, the conversion as shown in figure 10 is performed. However, the data 105S can be converted into a quantized data 901S having the same sign as the data 105S and the minimum absolute value which is equal to or larger than the absolute value of the data 105S among the powers of 2. Or the data 105S can be converted into a quantized

[Embodiment 6]

Figure 11 is a block diagram illustrating a structure of the waveform equalization controller according to the sixth embodiment. In figure 11, the waveform equalization controller of the sixth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 102 for estimating the error of the output signal 101S and outputting an error signal 102S, a step size quantization unit 1101 for converting a step size 104S into a quantized step size 1101S having a value of powers of 2 and outputting the quantized step size 1101S, and a coefficient updating amount calculation unit 1102 for calculating a tap coefficient updating amount 106S on the basis of the error signal 102S, the quantized step size 1101S and a data 105S to be used for the coefficient update.

Next, the operation of the waveform equalization controller according to the sixth embodiment is described

with reference to the figures. The error estimation unit 102 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, and outputs the estimated error as the error signal 102S. The step size quantization unit 1101 converts the step size 104S into the quantized step size 1101S having the maximum value which is equal to or smaller than the step size 104S among the powers of 2, and outputs the quantized step size 1101S. Figure 12 shows the relationship between the step size 104S and the quantized step size which is obtained by converting the step size 104S. Here, assume that when the step size 104S is "0" the quantized step size 1101S is also "0". The coefficient updating amount calculation unit 1102 receives the error signal 102S, the quantized step size 1101S and the data 105S. When the quantized step size 1101S taking on only the powers of 2 or "0" is used, the process of multiplying the error can be replaced with the shift operation. Therefore, the coefficient updating amount calculation unit 1102 replaces the process which is performed by the two-time multiplication in the prior art with one multiplication and one shift operation, and outputs the tap coefficient updating amount 106S.

As described above, according to the waveform equalization controller of the sixth embodiment, the step

size 104S is converted by the step size quantization unit 1101 into the quantized step size 1101S having a value of the powers of 2, and the tap coefficient updating amount 106S is obtained using the quantized step size 1101S. Therefore, in the coefficient updating amount calculation unit 1102, the multiplication can be replaced with the shift operation. Accordingly only one multiplier for calculating the coefficient updating amount of one tap is required, whereby the circuit scale can be reduced.

In this sixth embodiment, when the step size 104S is to be converted into the quantized step size 1101S, the conversion as shown in figure 12 is performed. However, the step size 104S can be converted into a quantized step size 1101S having the minimum value which is equal to or larger than the step size 104S among the powers of 2. Or the step size 104S can be converted into a quantized step size 1101S having a value which is nearest to the step size 104S among the powers of 2.

[Embodiment 7]

A waveform equalization controller according to the seventh embodiment will be described with reference to the figures.

Figure 13 is a block diagram illustrating a structure of the waveform equalization controller according to the seventh embodiment. In figure 13, the waveform

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Next, the operation of the waveform equalization controller according to the seventh embodiment is described with reference to the figures.

Figure 27 is a flowchart showing the operation of the waveform equalization controller according to the seventh embodiment. Figures 14(a)-14(d) are diagrams for explaining the timing of the tap coefficient update in the waveform equalization controller of the seventh embodiment.

The error estimation unit 1303 estimates the error on the basis of the output signal 101S output by the waveform equalizer 101 to be used for the tap coefficient update, generates the error signal 102S on the basis of the estimated error, and outputs the error signal 102S (step S501). Here, the error estimation unit 1303 generates the error signal 102S on the basis of Stop&Go algorithm. As shown in figure 14(d), the coefficient update timing control unit 1301 turns the update timing signal 1301S ON at the first symbol after a predetermined symbol interval (in this case "n" symbols, "n" being an integer of 1 or more) or more from the previous coefficient update timing and when the error signal 102S is not "0". At other symbols, the update timing signal 1301S is turned OFF (step S502). The coefficient updating amount calculation unit 1302 receives the error signal 102S, the step size 104S and the data 105S only when the update timing signal 1301S is ON, then performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S503). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S501 to S503 and the update of the tap coefficient in the waveform equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

In this seventh embodiment, as shown in figure 14(d), the substantial coefficient update interval is approximately $(n+1)$ symbols and therefore the interval is reduced about by half with relative to the prior art.

As described above, according to the waveform equalization controller of the seventh embodiment, the coefficient updating amount calculation unit 1302 comprises the coefficient update timing control unit 1301 for

In this seventh embodiment, the description is given of the waveform equalization controller using Stop&Go algorithm. However, the present invention is not limited to this waveform equalization controller. For example, the present invention can be also applied to a waveform equalization controller which may make the error signal 102S "0", i.e., stop the coefficient update operation in some states of the input or output signal.

In addition, the coefficient update timing control unit 1301 of the seventh embodiment is not limited to the unit which turns the update timing signal 1301S ON at the first symbol after "n" or more symbols from the previous coefficient update timing and when the error signal 102S is not "0". For example, a coefficient update timing control unit which monitors the error signal 102S thereby turning the update timing signal 1301S ON, such as a coefficient update timing control unit which turns the update timing signal 1301S ON at the second symbol after "n" or more symbols from the previous coefficient update timing and when the error signal 102S is not "0" is included

In addition, in this seventh embodiment, the timing of the coefficient update is controlled by turning the update timing signal 1301S ON or OFF. However, the present invention is not limited to this. For example, the update timing for the tap coefficient can be controlled by changing the kind of an identifier included in the update timing signal 1301S. In this embodiment, "generating the update timing signal 1301S" includes turning the update timing signal 1301S ON or OFF.

A waveform equalization controller according to the eighth embodiment of the present invention will be described with reference to the figures.

Figure 15 is a block diagram illustrating a structure of the waveform equalization controller according to the eighth embodiment. In figure 15, the waveform equalization controller of the eighth embodiment comprises a waveform equalizer 101 for outputting an output signal 101S which is obtained by reducing the transmission line distortion of an input signal 100S on the basis of the LMS algorithm, an error estimation unit 1501 for estimating the error of the output signal 101S and outputting an error signal 1502S, and a coefficient updating amount calculation unit 103 for calculating a tap coefficient updating amount 106S on the

Next, the operation of the waveform equalization controller according to the eighth embodiment is described with reference to the figures. Here, the description is given taking a case where the input to the waveform equalizer is the DTV signal as an example.

The output error estimation unit 1502 estimates the output error which is an error between the most likely symbol value and the output signal 101S output by the waveform equalizer 101, and generates the output error signal 1501S (step S601). The coefficient updating error generation unit 1503 receives the output error signal 1501S and the output signal 101S, generates a value of 25% of the output error signal 1501S as the error signal 1502S for the output

As described above, according to the waveform equalization controller of the eighth embodiment, the coefficient updating error generation unit 1503 for converting the output error signal into the value of 25% of the output error signal 1501S and outputting the value is provided, in place of the coefficient updating error generation unit converting the output error signal into "0" and outputting the error signal in the Stop&Go algorithm. Therefore, the error signals which can be used for updating the tap coefficient are increased in number and the convergence speed of the waveform equalizer 101 can be

As described above, according to the waveform equalization controller of the eighth embodiment, the coefficient updating error generation unit 1503 for converting the output error signal into the value of 25% of the output error signal 1501S and outputting the value is provided, in place of the coefficient updating error generation unit converting the output error signal into "0" and outputting the error signal in the Stop&Go algorithm. Therefore, the error signals which can be used for updating the tap coefficient are increased in number and the convergence speed of the waveform equalizer 101 can be

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Next, the operation of the waveform equalization controller according to the ninth embodiment is described with reference to the figures. Here, the description is given taking a case where the input to the waveform equalizer 101 is the DTV signal as an example.

The output error estimation unit 1502 estimates the output error as the error between the most likely symbol value and the output signal 101S output by the waveform equalizer 101, and generates the output error signal 1501S (step S701). The error rate measuring circuit 1703 turns the error rate signal 1702S ON when the error rate indicating a rate of the error included in the output signal 101S from the waveform equalizer 101 becomes equal to or larger than a predetermined value, for example 10%, and turns the error

The coefficient updating error generation unit 1702 receives the output error signal 1501S, the output signal 101S and the error rate signal 1702S, and when the error rate signal 1702S is ON it outputs the same signal as the error signal as shown in figure 22(b) on the basis of Stop&Go algorithm like in the prior art. When the error rate signal 1702S is OFF, the output error signal 1501S shows a nearly correct value. Therefore, the conversion on the basis of Stop&Go algorithm is not performed and the output error signal 1501S is output as it is as the error signal 1701S (step S703). Figure 18 shows the relationship between the output error signal 1501S and the error signal 1701S in the case where the error rate signal 1702S is OFF. The coefficient updating amount calculation unit 103 receives the error signal 1701S, the step size 104S and the data 105S, performs the multiplication of these, and outputs the tap coefficient updating amount 106S (step S704). Then, the tap coefficient updating amount 106S is used in the waveform equalizer 101 to update the tap coefficient shown by (Expression 1). Here, the processes of steps S701 to S704 and the update of the tap coefficient in the waveform

equalizer 101 are repeated as long as the waveform equalization is performed in the waveform equalizer 101.

As described above, according to the waveform equalization controller of the ninth embodiment, the error rate measuring circuit 1703 which turns the error rate signal 1702S ON or OFF according to the error rate of the output signal 101S in the Stop&Go algorithm, and the coefficient updating error generation unit 1702 which outputs the error signal 1701S which is obtained by converting part of the output error signal 1501S into "0" when the error rate signal 1702S is ON and outputs the output error signal 1501S as it is without converting the part into "0" when the error rate signal is OFF are provided. Therefore, the error signals 1701S which can be used for the tap coefficient update are increased in number and therefore the convergence speed of the waveform equalizer 101 can be improved.

In this ninth embodiment, the description is given of the case where the input is the DTV signal. However, the input is not limited to the DTV signal.

In addition, the threshold of the error rate at which the error rate measuring circuit 1703 switches the error rate signal 1702S between ON and OFF is set at 10% in this embodiment. However, the threshold is not limited to this value.

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Further, when the error rate signal 1702S is ON, the coefficient updating error generation unit 1702 generates the error signal 1701S on the basis of Stop&Go algorithm in this embodiment. However, the present invention is not limited to this. For example, the coefficient updating error generation unit can output the error signal 1502S as shown in figure 16(b) of the eighth embodiment when the error rate signal 1702S is ON. As long as the error signal 1701S output by the coefficient updating error generation unit 1702 when the error rate signal 1702S is ON is not the same as the output error signal 1501S, i.e., is a signal obtained by attenuating the output error signal 1501S in a predetermined range or at a predetermined ratio or making the output error signal 1501S "0", this is included in the scope of the present invention.

In addition, in this ninth embodiment, the error rate signal 1702S is generated by the error rate measuring circuit 1703 as ON or OFF. However, the present invention is not limited to this. For example, whether the error rate is equal to or more than the predetermined value or not can be shown by changing the kind of an identifier included in the error rate signal 1702S. In this embodiment, "generating the error rate signal 1702S" includes turning the error rate signal 1702S ON or OFF.

Further, when the output signal 101S of the waveform

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